Growth Patterns Among Seminomadic Pastoralists (Datoga) of Tanzania

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KEY WORDS Africa; herders; children; anthropometry; delayed maturation; catch-up growth; stunting; wasting; undernutrition; nutrition

ABSTRACT Anthropometric measurements made on 470 individual children (age 0–18 years) from a seminomadic population of Datoga pastoralists living in northern Tanzania were used to describe patterns of child growth. Comparisons with reference growth curves derived from American samples suggest that pastoral Datoga children grow poorly in this region. Body compositional changes with age differed markedly from the reference population. There were negligible fat gains through childhood, even among females. Comparison with data on other East African pastoralists showed that population growth performance is intermediate between that of nomadic and settled pastoralists. Little catch-up growth occurs during childhood, and adolescence appears to be delayed among males. The results contribute to the growing database on health indicators for African pastoralists and suggest a need for further research to investigate mechanisms for growth stunting in these populations. Am J Phys Anthropol 109:187–209, 1999. © 1999 Wiley-Liss, Inc.

Clinicians and anthropologists have long been interested in how environment influences patterns of child growth, but associations with subsistence practices remain poorly investigated. It has been hypothesized that much of the variation in body size among rural African populations may be attributable to differences in dietary adequacy, energy requirements, and infection rates among populations engaged in different subsistence practices (Wheeler, 1980). While there have been a number of recent surveys of nutritional status and food supply in sub-Saharan African pastoral populations (Benefice et al., 1984; Loutan and Lamotte, 1984; Loutan, 1985; Brainard, 1986, 1990; Nestel and Geissler, 1986; Bernus, 1988; Nestel, 1989; White, 1991; Galvin, 1992; Lindtjørn et al., 1992, 1993; Little et al., 1992; Hansen et al., 1993; Galvin et al., 1994; Gray, 1994; Shell-Duncan, 1995; Nathan et al., 1996), relatively few published studies have estimated patterns of child growth (Little et al., 1983, 1993; Dowler et al., 1986; Little and Johnson, 1987; Little and Gray, 1990b; Cameron, 1991; Sellen, 1996; Little, 1998).

The Eyasi Datoga are seminomadic pastoralists who keep cattle, sheep, and goats for milk, meat, and trade for grain (Klima, 1965; Borgerhoff Mulder, 1991; Sellen, 1995). This paper examines data from cross-sectional surveys of child anthropometry among the Eyasi Datoga living at three settlement areas. Objectives were to examine the distributions of anthropometric scores of children in relation to seasonality, settlement area, home environment, age-related work activities, and sex-biased parental investment

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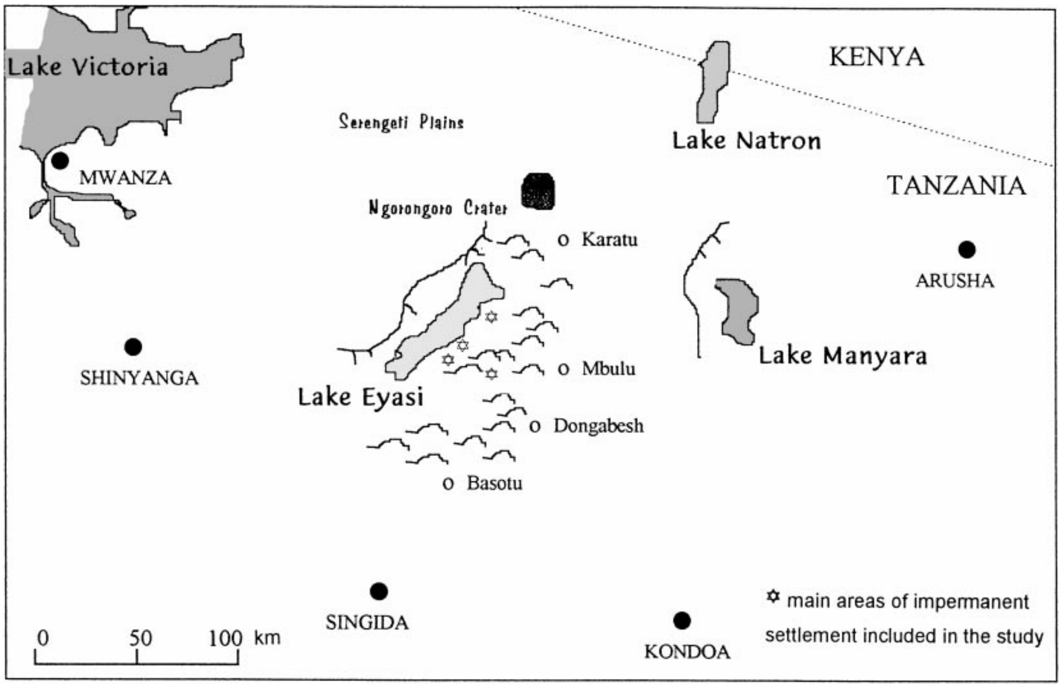


Fig. 1. Map showing location of the Eyasi area.

strategies, to establish the prevalence of indicators of undernutrition in the population, and to examine patterns of growth. Here we assess the overall growth pattern of the population by constructing mixed-longitudinal growth curves and comparing these to appropriate growth reference data.

MATERIALS AND METHODS

Subjects

The Datoga are Kalenjin-speaking pastoralists known to have occupied large areas of Tanzania and southern Kenya for much of the last millennium (Borgerhoff Mulder et al., 1989; Sellen, 1995). They have a recent history of territorial losses due to wars with the Maasai and Sukuma, aggressive German and British colonial policies, and postindependence encroachment by agriculturists and government projects (Kjaerby and Baynit, 1979; Lane and Pretty, 1990). Their present range is restricted to some of the more arid and least accessible areas of north and central Tanzania. Previous anthropological research focused on the Barabaig clan subsection that inhabits the relatively wet areas surrounding Mount Hanang (Klima, 1965; Blystad, 1992).

A cross-sectional survey approach was used to sample Datoga children living in the Lake Eyasi basin (Fig. 1). The Eyasi Datoga define themselves as people who herd cattle and subsist on herds of cattle, sheep, and goats, and all families had herds. Participant observation and household food surveys confirmed that few bush foods were consumed, and dietary studies showed that most calories consumed are derived from grain obtained through trade (Sellen et al., 1993). No adequate census data exist for the Datoga, and population estimates vary substantially from 30,000–200,000 (Borgerhoff Mulder, 1992). They are "seminomadic" (Umesao, 1968; Tomikawa, 1979), and have largely avoided economic, social, and political involvement in the state. It is not clear whether this is a cause or an effect of their poor political representation and strong discrimination within present-day Tanzania. Despite the availability of primary schools at villages in the area, few children are sent to school. Few men (approximately 60%) and

TABLE 1. Summary of cross-sectional anthropometric samples[1]

Initial sample and exclusions	Survey 1	Survey 2	Totals
Total number of children on which measurements were made	286 [121, 165]	158 [74, 84]	444 [195, 249]
Age not satisfactorily determined from informants	6 [3, 3]	21 [11, 10]	27 [14, 13]
Final sample size, 0–18 years	270 [116, 154]	131 [62, 69]	417 [181, 236]

[1] In brackets: males and females, respectively.

fewer women (30%) can speak KiSwahili, the official language and regional *lingua franca*. Illiteracy is almost universal.

Families base their activities at semipermanent family homesteads (*ghed*). Each ghed consists of a cluster of timber and earth huts, sheds for goats and calves, maize stores, and compounds for the larger livestock, all enclosed within a thorn brush stockade for protection against predators and human raiders. One or more (usually agnatically related) men, some or all of their wives and children, a few collateral kin, and a variable number of livestock occupy homesteads. All household members participate in herding tasks. Women collect water and fuel wood by hand. The diet consists of maize purchased from neighboring agricultural populations and animal products, supplemented by a few wild foods.

Demographic parameters for the Datoga population in the Eyasi area have been estimated for a sample that includes households from the present study (Borgerhoff Mulder, 1992). No modern forms of contraception are used, and total fertility is high in relation to other pastoral groups (Lane and Pretty, 1990; Roth, 1994). However, birth intervals are long, reflecting the interplay between prolonged breast-feeding practices (Sellen, 1998b), work outputs (Sieff, n.d.) and seasonal factors (Borgerhoff Mulder, 1992). Infant mortality approaches 20% and is high by national and international standards; mortality remains relatively high throughout life. The major causes of mortality are not well-investigated to date, but have been observed to include tetanus of the newborn, and dehydration and respiratory tract infections among young children. Malaria, diarrhea, gut parasites, and tuberculosis are prevalent among adults; the illnesses most commonly treated by local flying doctors are scabies, eye infections, and infected leg injuries sustained while walking in the bush. The diseases of cattle are many, and include several transmissible to humans: brucellosis, tuberculosis, tick-borne diseases, and anthrax. Physicians at one hospital near the study site reported in 1989 that several Datoga patients had presented with symptoms of AIDS or tested HIV-positive.

Data collected in both cross-sectional and longitudinal studies were used to describe growth patterns for children in the population. A census and a round of anthropometric measurements were carried out for children of all ages during two cross-sectional surveys between April–June 1989 and January–March 1991. These surveys were designed to achieve maximum coverage of households in the area and were 80% successful (Sellen, 1995). A total of 444 children was measured (Table 1). In 27 cases, mainly older adolescents, the age estimate obtained from informants at the time of measurement was deemed unreliable and therefore their measurement series were excluded from analysis. Among the series retained for analysis there was an overlap of 28 subjects measured in both surveys. Thus, a total of 389 subjects measured in at least one of the surveys was included in this analysis. Anthropometric measures were also taken monthly between the end of the long rains (May) and the beginning of the short rains (December) of 1992 for 78 children under age 3 years living in two Datoga settlements as part of a prospective study of growth and feeding practices (Sellen, 1998b).

Anthropometric measures used

Since the target population lives scattered over a wide area, and individual women have little time available to walk or bring their children to central meeting points, each of the homesteads was visited in turn and the measurement equipment set up

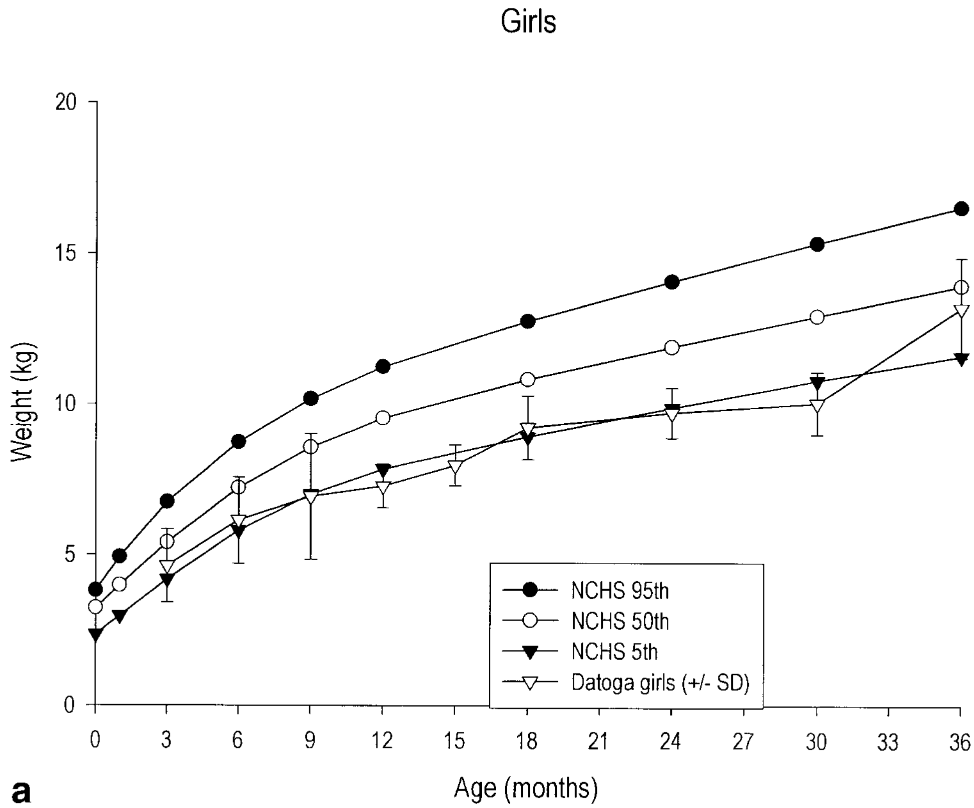


Fig. 2.

within the compound or under a nearby shade tree. On any single visit, not all subjects would be home, and often repeat visits were necessary at different times of day, so as to include as many women and children of herding age as possible. The same observer (D.W.S.) made every measurement following standard procedures (Jelliffe and Jelliffe, 1989; Frisancho, 1990; Gibson, 1990). Barefoot standing height was measured to the nearest millimeter using a portable anthropometer (Model 101, Seritex, Inc., East Rutherford, NJ), attached to a flat metal platform which was dug level into the ground using a hoe and a spirit-level. Subjects were encouraged to stand tall with heads level, and the chin-support method was used to raise the younger children to the correct height. Any child that could stand was encouraged to be measured, and children as small as 75 cm (and as young as 12 months) were successfully measured in this way. The need to carry all equipment on foot precluded the use of a board in the surveys, so that measures of recumbent length or stature were not taken for infants and children under 24 months (n = 56, survey 1; n = 33, survey 2). However, recumbent length was measured for all 81 children in the longitudinal study.

Weights of children were measured to the nearest 0.1 kg using a digital scales (survey 1, 12-v battery-operated Weylux Model 850; survey 2, AA battery-operated Soehlner Model 7701; both from CMS Weighing Ltd., London, UK). If young children were very fussy or sick, they would be weighed by difference with the mother or caregiver standing on the digital scales with and without the young child. Infants were weighed directly with a spring balance to the nearest 0.2 kg (Salter Industrial Measurement Ltd., West Bromwich, West Midlands, UK). Naked weight was measured for

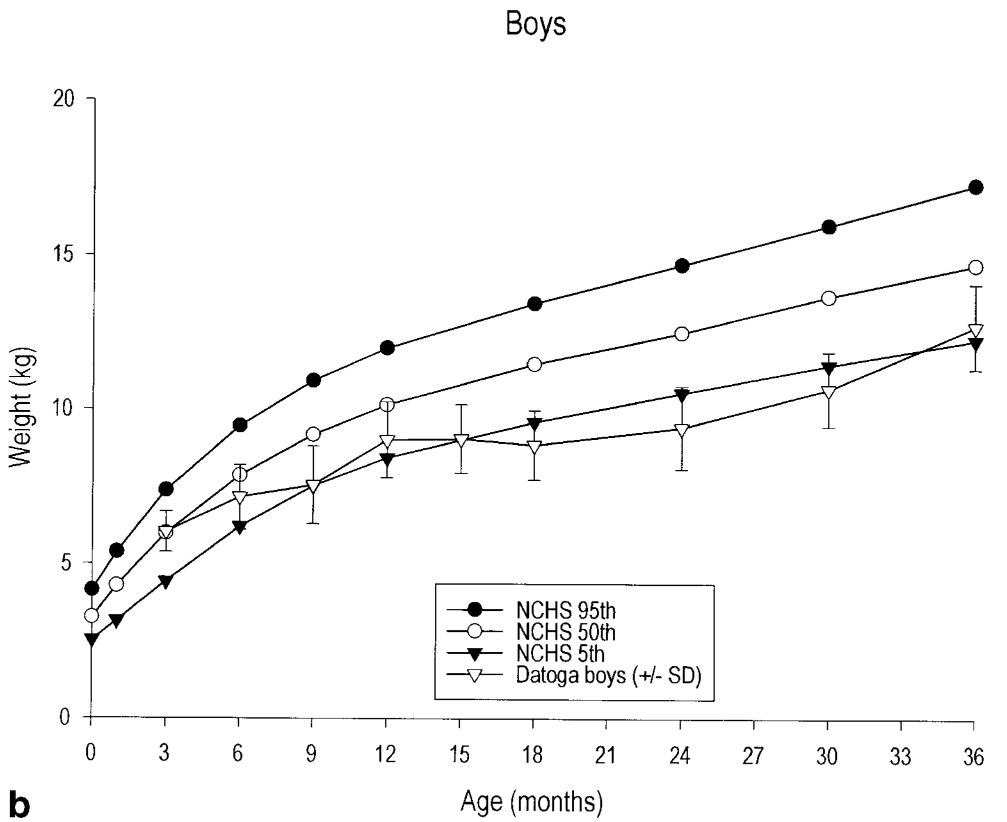


Fig. 2. Average weight gains of young Datoga children plotted against multiethnic American reference data (Department of Health, Education, and Welfare, 1977b): mixed-longitudinal data, 190 measures on 78 children, means ± SD. **a:** Girls. **b:** Boys.

all younger children. For older children, shoes were removed but clothing and jewelry were worn at the time of weighing and each item was tallied. Most clothing items were of a limited number of types of cloth wrap (akin to a Roman *toga*) which are traditionally sold and used in the area (KiSwahili: *mashuka*, *vikoi*) and are distinguishable by material, color, and size. Therefore, the mean weight of a random sample of each type was calculated. These mean values were then used to make standard subtractions from the gross weights of individuals who wore particular garments at measurement, and the resulting estimated unclothed weights were used in analysis. The midpoint of the brachium was located by measurement from the acromion of the shoulder to the olecranon process of the elbow, and the circumference at that point measured to the nearest millimeter using a small steel tape (Rabone Chesterman Ltd., Birmingham, UK). All arm measurements were taken on the right side so as to maximize comparability to North American reference data (Martorell et al., 1988). Two skin folds were measured in each subject to the nearest 0.2 mm with a Harpenden skin-fold caliper (Hemco Corporation, Holland, MI), taking the average of three separate readings. Triceps skin-fold thickness (TSF) was measured at the previously marked midpoint of the right upper arm (except where noted above), and subscapular skin-fold thickness (SSF) was measured at the inferior angle of the right scapula.

No birth records exist for the population. Year and month of birth of children were therefore obtained through interviews with parents or other family members (USAID,

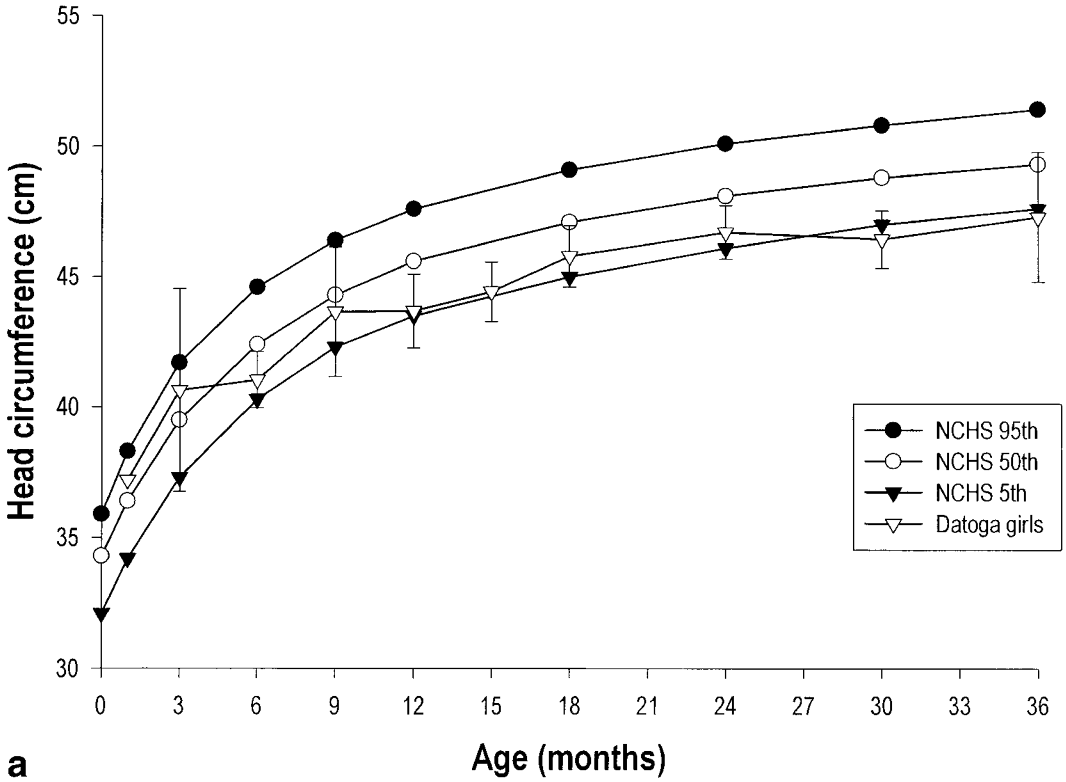


Fig. 3.

1979). A standard cross-checking methodology developed by small population demographers was applied (Howell, 1979; Cronk, 1989; Leslie and Gage, 1989; Blurton Jones et al., 1992; Borgerhoff Mulder, 1992; Pennington and Harpending, 1993; Hill and Hurtado, 1996). Informants were asked to place the date of birth of each child on a local calendar of events developed by previous researchers and updated by the present author (Sellen et al., 1993). The date of birth was arrived at to the nearest month by consensus in almost all instances. Informants apparently had little difficulty naming and agreeing upon dates for children under 5 years, although there was more difficulty in recalling, and more debate over, the dates of birth of children in their teens. Secondary sexual characteristics were not systematically observed in adolescents because of the constraints of the conditions of measurement (out in the open) and difficulty in recruiting female research assistants.

Data for height, weight, age, and sex were used to compare all individual children to the appropriate CDC/NCHS/WHO international reference based on multiethnic US samples collected by the Fels Research Institute and the National Center for Health Statistics (Department of Health, Education, and Welfare, 1977a,b). Upper arm muscle area (UMA without adjustment for estimated bone area) and arm fat index (AFI: the percentage of fat in the upper arm) were estimated from the measures of upper arm circumference (MUAC) and triceps skin fold (TSF) according to the method of Frisancho (1990, p.20). The distribution of each of these measures of body composition by age and sex was then compared to that estimated for African Americans in the NHANES I and NHANES II surveys conducted by the US National Center for Health Statistics (Frisancho, 1990). Statistical analyses were performed using the SAS package (SAS Institute, 1989) on a personal computer. Paired

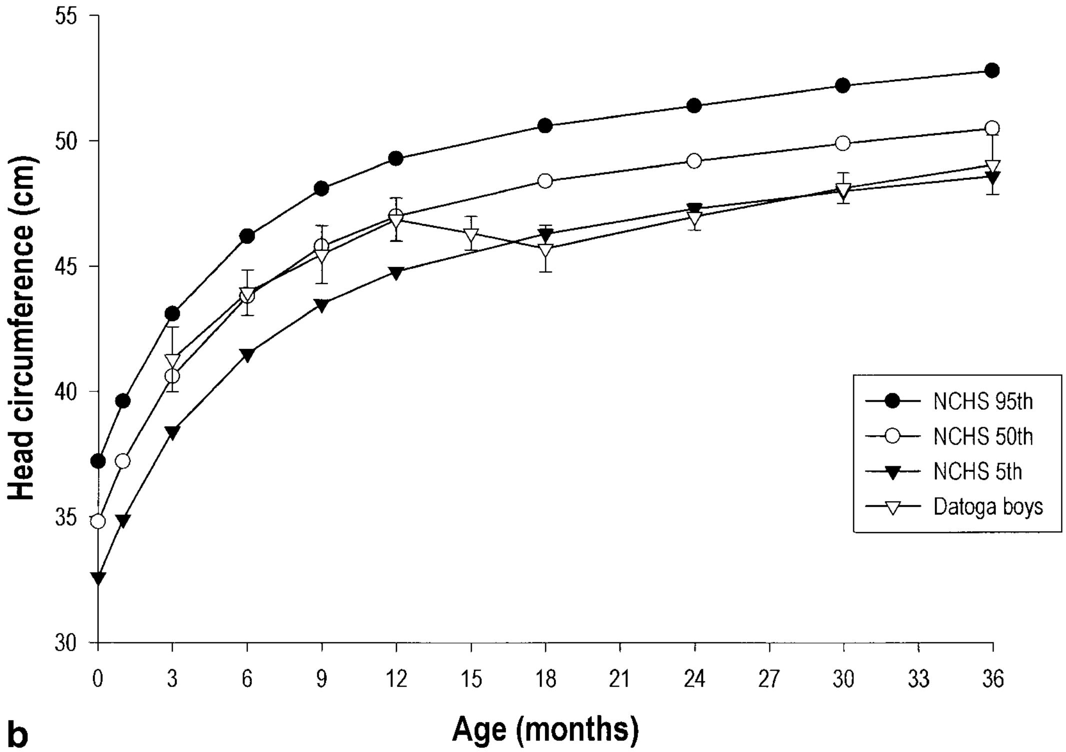


Fig. 3. Average head circumference of young Datoga children plotted against multiethnic American reference data (Department of Health, Education, and Welfare, 1977b): mixed-longitudinal data, 190 measures on 78 children, means ± SD. **a:** Girls. **b:** Boys.

and unpaired t-tests, χ^2 tests, and analyses of variance were performed at the 5% level of significance.

RESULTS

Mixed-longitudinal estimates of growth in young children

Early growth faltering was examined using the measures of weight and head circumference made on 78 individuals included in the longitudinal study of children under 3 years of age. The mixed cross-sectional growth patterns observed in this sample were compared to the cross-sectional patterns observed in the multiethnic NCHS/CDC/WHO reference population (Figs. 2, 3). Growth faltering of infants was clear after age 3 months for girls and age 6 months for boys. The mean weights for age fell to the 5th percentile by 9 months of age and below the 5th percentile after 18 months (Fig. 2). Lengths for age were also below reference medians at all ages 0–3 years. Mean head circumference remained close to the reference median until 9 months for girls and 12 months for boys, after which it fell at or below the 5th percentiles (Fig. 3).

Comparison of growth in weight and stature with US reference data

To facilitate comparison with other pastoral populations for which growth data are commonly presented using 1-year intervals, Table 2 shows the mean anthropometric values for girls and boys measured in both cross-sectional surveys grouped by age to the nearest year, including repeated measures on 28 children. Means were found to fall below the medians of the NCHS reference curves at all ages. To provide a more refined visual description given the constraints of the small sample and to examine changes in sampling error with age, mixed-longitudinal growth curves were constructed

TABLE 2. Means and standard deviations of anthropometric measures taken on a cross section of children from a seminomadic Datoga population[1]

Age (years)	N	HT Mean	HT SD	TRUWT Mean	TRUWT SD	WHI Mean	WHI SD	TRISF Mean	TRISF SD	SUBSF Mean	SUBSF SD	SUMSF Mean	SUMSF SD	MUAC Mean	MUAC SD
Females															
<1	21	*	*	6.8	2.0	*	*	7.9	2.2	5.9	2.0	13.7	3.8	12.9	0.8
1–1.99	19	76.9	5.2	8.4	1.4	16.1	2.4	8.5	1.8	5.6	2.0	14.0	2.5	14.0	1.1
2–2.99	17	89.5	7.0	11.2	1.9	14.6	2.1	9.2	2.1	5.1	1.0	14.3	2.4	14.6	1.0
3–3.99	20	94.6	9.9	13.1	2.4	14.6	1.2	7.4	2.2	4.8	1.1	12.2	2.5	14.4	0.8
4–4.99	19	97.5	8.6	13.8	2.3	14.6	1.4	7.4	1.7	4.7	1.2	12.2	2.6	14.5	0.9
5–5.99	24	107.6	9.7	15.9	3.2	13.8	1.0	5.9	1.7	4.5	1.2	10.4	2.4	14.8	1.1
6–6.99	10	111.5	8.1	16.8	3.2	13.4	1.1	6.0	2.5	4.1	0.6	10.1	3.0	14.9	1.3
7–7.99	14	120.2	6.2	19.9	2.4	13.8	1.0	4.7	1.3	4.0	0.7	8.7	1.9	15.4	1.1
8–8.99	6	125.7	5.1	22.1	1.3	14.0	0.6	5.7	1.4	4.7	0.7	10.3	1.6	16.3	0.8
9–9.99	16	125.1	8.2	21.5	3.9	13.6	1.3	5.9	1.3	5.0	0.8	10.8	1.7	15.7	1.3
10–10.99	12	131.9	10.2	23.7	4.2	13.3	1.3	5.3	1.6	4.9	1.3	10.2	2.4	16.2	1.5
11–11.99	12	135.1	7.0	27.0	4.2	14.7	1.5	6.0	1.7	4.8	0.7	10.8	2.1	17.0	1.8
12–12.99	12	137.4	7.1	28.6	6.6	15.1	2.3	6.9	2.0	6.0	2.7	13.0	4.3	17.9	2.2
13–13.99	7	149.2	10.6	34.2	6.5	15.7	2.2	7.1	2.9	5.0	1.1	12.1	3.6	18.9	1.2
14–14.99	10	149.1	6.3	35.5	5.3	16.0	2.4	8.1	3.7	5.6	2.7	13.7	5.1	19.5	1.8
15–15.99	9	152.4	8.1	38.0	8.2	16.3	2.1	7.9	3.0	4.4	2.3	12.3	2.6	20.7	2.5
16–16.99	4	156.7	5.8	38.3	7.4	15.5	2.5	5.6	1.9	6.8	2.7	12.5	4.6	20.1	2.9
17–17.99	2	166.8	5.6	46.2	1.4	16.6	0.6	5.9	0.0	6.7	0.4	12.6	0.4	20.1	0.5
18–18.99	2	149.3	6.7	41.0	9.2	18.3	2.5	6.9	2.3	6.6	2.1	13.4	4.4	20.0	1.3
Total	236														
Males															
<1	24	*	*	6.5	1.7	*	*	8.1	2.1	6.2	1.9	14.0	3.5	13.4	1.1
1–1.99	11	76.8	5.0	9.8	1.1	15.4	0.0	9.2	1.9	5.4	1.7	14.5	3.2	14.2	1.5
2–2.99	16	84.7	4.7	10.9	1.4	15.6	1.0	9.2	2.5	5.1	1.3	14.3	3.4	13.8	0.8
3–3.99	22	92.7	6.1	12.8	2.5	15.4	1.5	8.3	2.3	4.9	1.0	13.2	3.1	14.7	1.4
4–4.99	10	99.1	5.7	15.6	2.6	15.3	0.9	7.5	1.3	4.5	1.1	12.0	1.5	14.7	1.3
5–5.99	14	104.0	8.9	15.7	2.3	14.5	1.4	7.6	2.7	4.6	0.8	12.3	3.3	14.7	1.1
6–6.99	12	112.4	5.9	17.6	2.7	13.8	1.3	5.8	2.1	3.9	0.6	9.7	2.6	14.9	1.4
7–7.99	9	118.2	9.6	20.2	4.0	14.3	1.1	4.8	0.8	4.4	0.6	9.3	1.2	15.0	1.3
8–8.99	5	124.2	3.9	21.6	1.9	14.0	0.7	5.0	1.2	4.6	0.9	9.6	2.0	14.9	1.0
9–9.99	12	126.3	2.9	23.2	2.0	14.6	1.0	5.1	0.9	4.6	1.0	9.6	1.7	15.8	1.2
10–10.99	9	132.2	9.4	24.5	3.8	13.9	1.1	4.2	1.0	3.9	0.2	8.1	1.1	15.2	1.0
11–11.99	10	136.1	5.8	27.6	2.5	14.9	1.3	5.3	0.9	4.5	0.7	9.8	1.6	15.7	2.0
12–12.99	9	142.6	9.2	29.1	4.3	14.3	0.4	5.1	1.1	5.0	1.8	10.1	1.9	15.8	1.7
13–13.99	5	139.0	8.7	29.7	5.0	15.3	0.7	5.0	1.5	5.0	1.5	10.0	2.5	18.9	0.9
14–14.99	8	141.4	9.4	30.1	4.8	15.0	1.0	5.7	1.8	4.8	1.4	10.4	3.2	17.6	2.3
15–15.99	3	145.4	2.6	35.1	2.7	16.6	0.7	6.0	0.3	4.8	0.6	10.8	0.4	18.9	0.8
16–16.99	2	159.1	2.8	36.5	5.9	14.4	1.8	3.4	0.9	3.6	0.6	6.9	1.6	17.8	3.3
Total	181														

[1] SD, standard deviation of the mean; HT, height (cm); * missing data; WT, weight (Kg); WHI, weight/height^2 (Kg/m^2); TRISF, triceps skin fold (mm); SUBSF, subscapular skin fold (mm); SUMSF, sum of triceps and subscapular skin folds (mm); MUAC, mid upper arm circumference (cm).

after pooling data from both surveys. Means and standard deviations of weights and heights of boys and girls were calculated at 6-month intervals for children younger than 12 years and at annual intervals for children 12–18 years (Figs. 4, 5). Estimates based on sample sizes less than three were not plotted.

Mean weights of girls were found to fall a little above the 5th percentile of standards until about the ninth year, after which there was a drop in weights for age, and a marked increase in the variance between individuals, which remained through the teenage years (Fig. 4a). The data suggest that the mean weight of adult women in this population (approximately 47 kg) is achieved by 18 years of age (Table 2), which is also the median age at marriage. In contrast, mean weights of boys were found a little below the 5th percentile of standards until about the ninth year, after which mean weights for age fell increasingly below the 5th percentile. At 16 years the mean weight was but 60% of the standard median (Fig. 4b).

Mean heights of girls were found to fall above the 5th percentile until the ninth year (Fig. 5a). Between 5–9 years they fell around

the 25th percentile. Thereafter they were a little below the 5th percentile until the sixteenth year. Growth in stature of boys appeared to be more strongly compromised. Mean heights of boys were found to fall near the 5th percentile of the reference population (approximately 90% of reference median) until the tenth year and below it into the teens (Fig. 5b).

Comparison of growth in weight and stature with Turkana pastoralists

Mean weights and heights by age in years were also compared for each sex with those available from similar studies of both nomadic and settled Turkana pastoralists (Little et al., 1983, 1993; Little and Gray, 1990a) and with means for the African American subsample of the US reference population (Figs. 6, 7). This approach was chosen because the slightly differing rates of height and weight gain with age among ethnic groups are obscured in the ethnically mixed NCHS/CDC/WHO sample (Frisancho, 1990; Gibson, 1990). Although the African American curves are similar to the aggregate curves, because there are some differences among older children they are therefore the most appropriate available reference for the present population. All three of these "pastoral" populations fell below the US reference means. Datoga girls were on average a little taller and heavier than nomadic Turkana girls until 10 years of age; after 10 years, heights became very similar, but Datoga girls tended to be heavier for age as teenagers. Datoga boys were on average taller and heavier for age than nomadic Turkana boys until 13 years of age, after which there appeared to be little consistent difference. Datoga children of both sexes were of similar weights for age as settled Turkana, at least over the age range for which data could be compared, but were appreciably shorter.

Age-related changes in fat reserves

Children of both sexes showed a decrease in measures of adiposity between 2–7 years of age (Fig. 8). After 10 years of age, girls showed a gradual increase in summed skin folds, whereas boys showed little change. Mean values of estimated arm fat and muscle areas of children were found to be smaller than those from the African American reference population at all ages from 2–18 years for both boys and girls (Fig. 9). Among girls, mean muscle areas, though consistently lower than standards, showed rates of increase with age from 2–9 years similar to those of standards (Fig. 9a). Upper-arm fat area of girls increased very little, even in the teenage years, in marked contrast to standards. At 17 years of age, mean areas of both muscle and fat were still much lower than the means found for adult married women, suggesting that some tissue growth continues after marriage. Muscle areas of boys were found to increase, on average, at a slow rate relative to standards (Fig. 9b). Boys in the 8–12-year age range had very similar upper arm muscle areas in this sample, suggesting that perhaps rates of gain in lean body mass were slowed in late childhood. Most notably, there was little appreciable arm muscle growth between 9–13 years. By the late teens, mean muscle areas were less than 50% of those in the US reference population. Mean arm fat areas decreased until 8 years of age, as is the pattern in the reference population, but remained very low thereafter, with little appreciable preadolescent or adolescent fat gains.

DISCUSSION

Quality of the growth data

A strong attempt was made to obtain as large and representative a sample of child measures as possible under the logistic and technical constraints encountered in the field. In spite of these efforts, the study was subject to several of the potential sampling biases typical of most published studies of seminomadic African pastoralists (Sellen, 1996). The sample was biased towards girls, and teenagers were almost certainly underrepresented. Ages were difficult to ascertain reliably because of the imprecision of age determination. Even though birth dates were collected to the nearest month, there was some "heaping" of age estimates to the nearest year for teenagers. However, the small proportion (15 cases) of height-for-age Z-scores (HAZ), greater or less than 2 standard deviations from the mean for the population measured in each survey suggested

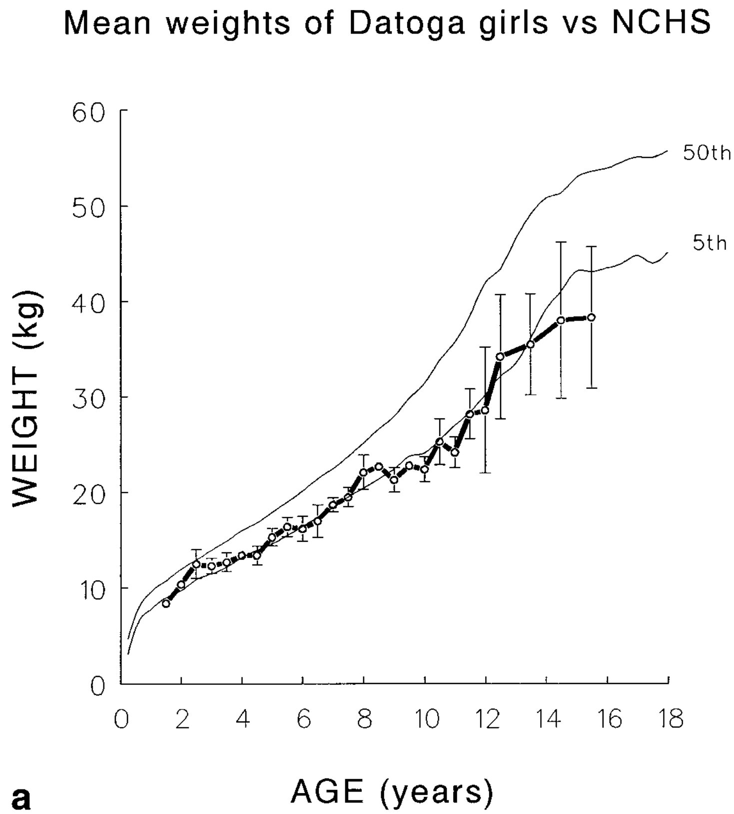


Fig. 4.

that most age estimates were reasonably accurate and not systematically biased for either sex or any particular developmental stage.

The results are unlikely to reflect biases towards certain subsections of the population, such as poorer or less mobile households. This is because of the relatively large sample sizes, the inclusion of virtually every household in a defined large area of the Eyasi valley system, the careful use of ethnographic techniques of age estimation, and the rigorous exclusion of potentially invalid or unrepresentative data. They are therefore deemed adequate for drawing valid inferences about the growth status of children within the population.

Early childhood growth faltering

The cross-sectional data from the two surveys indicated that much of the deficit in growth relative to the reference was already established by the second year of age. The mixed-longitudinal study of infants and weanlings in the Eyasi Datoga shows that growth deficits occur in the first 3–6 months of life and occur earlier for girls (Fig. 2). There are likely to be a number of contributing causes. First, adult women are of poor nutritional status and are likely to give birth to babies of low birth weight (Sellen, 1995). Unfortunately, since only a small proportion of Datoga infants are weighed at birth in a clinic setting, no data on birth weights are available and this hypothesis cannot be directly tested. Second, early growth faltering is likely to be linked with inadequate food intake. A proportion of households are estimated to have inadequate food supplies (Sellen, 1995). The Datoga diet consists largely of maize gruel or stiff porridge, which is a low nutrient density food, only infrequently supplemented with animal milks, leafy vegetables, and

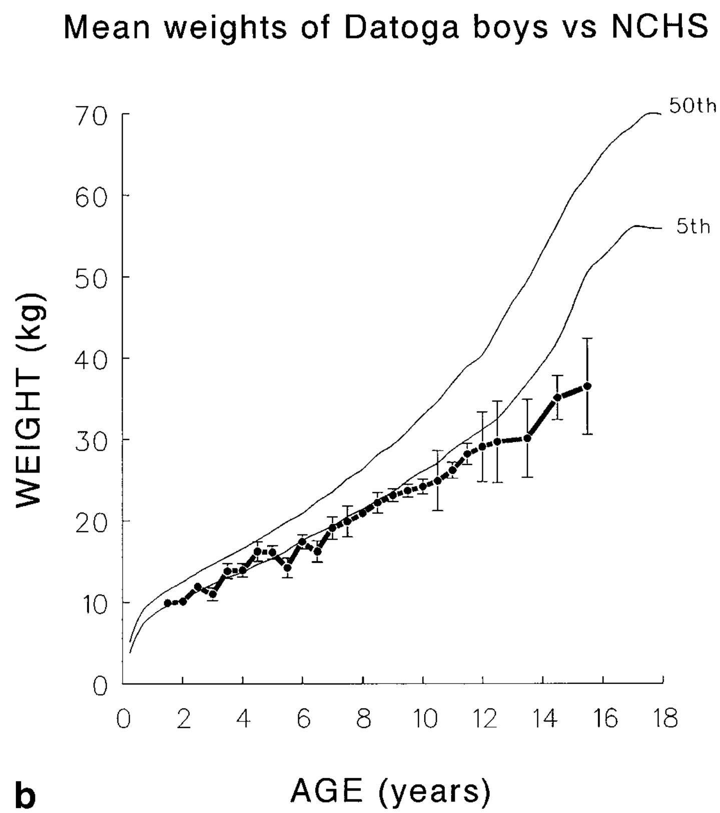


Fig. 4. Age distribution of mean weights of Datoga children, 0–18 years, plotted against multiethnic American reference data. Solid lines show mixed-longitudinal growth curves of Datoga children ± 1 SD. Dotted lines show 50th and 5th percentiles of the NCHS reference data (Hamill et al., 1979). **a:** Mean weights of Datoga girls, n = 217 child measures, 0–16 years. **b:** Mean weights of Datoga boys, n = 173 child measures, 0–16 years.

meat. Observations of infant and young child feeding practices suggest that younger children are buffered from the seasonal fluctuations in household food supply by continued breast-feeding of long duration and by the mother's relinquishing her intrahousehold food allocations to her offspring. Although children's nutritional status does not appear to be related to seasonal factors that might influence food availability, young child diets remain inadequate in key respects (Sellen, 1998b). In comparison to standard weaning recommendations, children are supplemented with animal milks at a relatively young age (median 2 months) and complemented with solid foods at a relatively late age (median 11 months in the case of introduction of maize porridge). Thus, despite an almost universal initiation of breast-feeding, exclusive breast-feeding is rare and of short duration, while the gruel and porridge commonly used as the principal weaning foods are unlikely to satisfy the nutrient needs of weanlings. Young child feeding practices are likely to have negative effects on growth.

Third, early growth faltering is likely to be linked with high rates of infection (Moy et al., 1994; Shell-Duncan, 1995; Nathan et al., 1996). Datoga children under 5 years show high mortality (Borgerhoff Mulder, 1992). The importance of young child morbidity in reducing young child food intakes and modifying maternal feeding practices was assessed in the longitudinal study of children under 3 years from caregiver reports of the subject child's illnesses during the 24 hr prior to each visit. The symptoms were

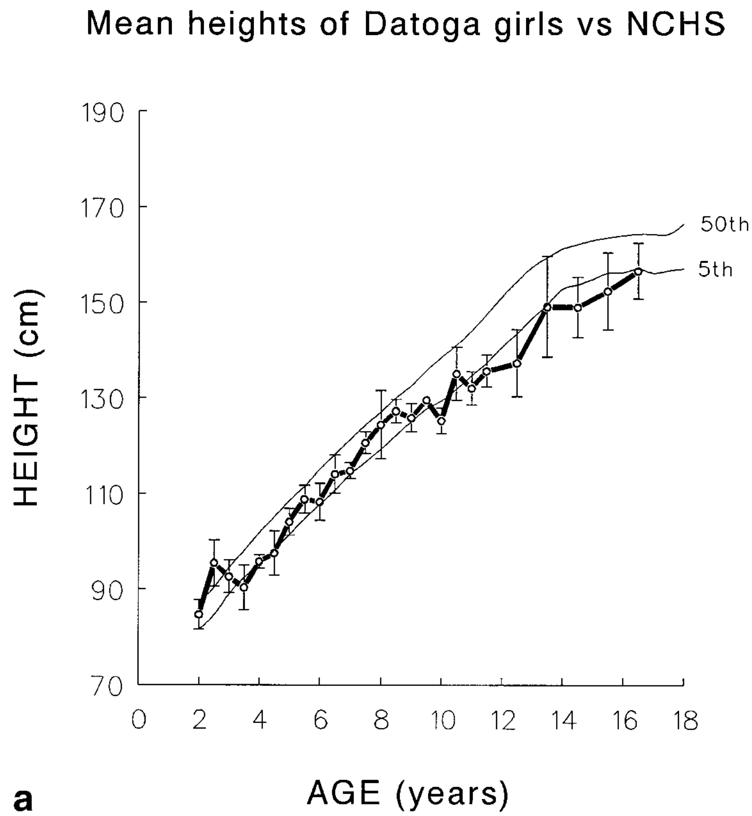


Fig. 5.

described by the caregiver without leading questions from the interviewer. Symptoms of nondiarrhea illnesses affected children younger than 3 years on over 40% of days, and usually occurred simultaneously with symptoms of diarrhea (Table 3). Among these, symptoms of febrile diseases, principally malaria, and respiratory infections were most prevalent. The most common symptom of illness was diarrhea, which affected children in this sample on almost 1 out of 3 days. These patterns of illness among young children suggest that growth may be compromised by frequent and extended periods of fever and anorexia.

We have evidence that social factors also strongly influence the autecology of young child growth among the Datoga, not simply by affecting food availability, food intakes, and susceptibility to infection, but by subtly affecting components of young child care and feeding behaviors. For example, maternal work-related factors interfere with the ability of mothers to frequently breast-feed their young children and result in early introduction of contaminated liquid foods, reduced breast-milk intakes, and early cessation of breast-feeding (Sellen, 1998b). The growth of young children is associated with the different positions within polygynous marriages occupied by their mothers (Sellen, 1995, 1999). There is also indirect evidence that both early and later child growth performance is associated with complex co-wife effects which derive from differential maternal workloads, such that senior wives do less demanding or time-consuming work, or control more material resources within households (Sellen et al., 1999). Finally, it is highly likely that differences in workloads among women in households of different size and composition may also play a role. Women in households with more adult laborers and fewer dependent children may do less de-

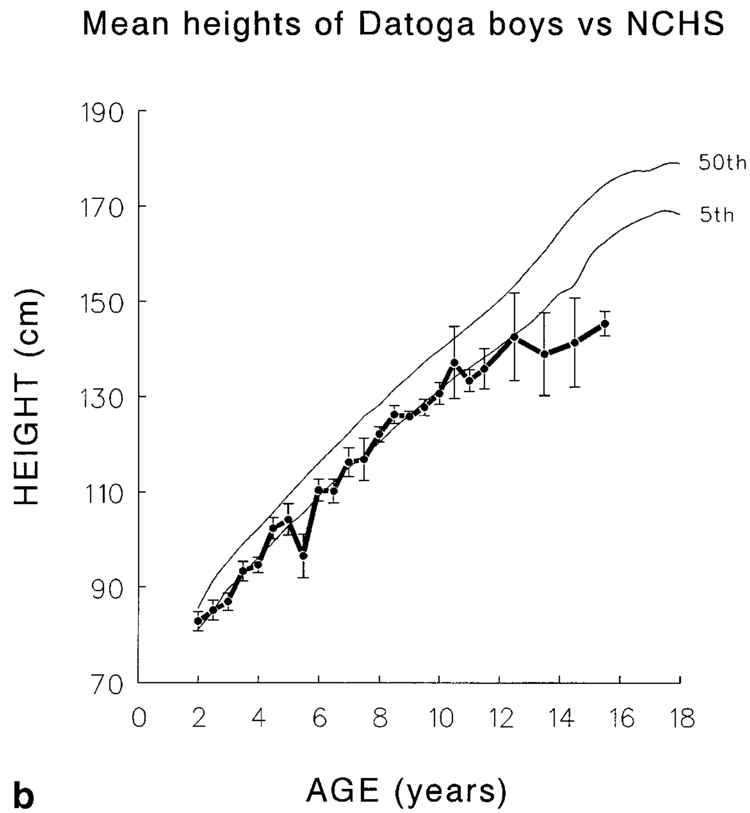


Fig. 5. Age distribution of mean heights of Datoga children, 1–18 years, plotted against multiethnic American reference data. Solid lines show mixed-longitudinal growth curves of Datoga children ± 1 SD. Dotted lines show 50th and 5th percentiles of the NCHS reference data (Hamill et al., 1979). **a:** Mean heights of Datoga girls, n = 200 child measures, 1–16 years. **b:** Mean heights of Datoga boys, n = 154 child measures, 1–16 years.

manding or time-consuming work (Sieff, 1997).

Lack of catch-up growth and adolescent growth "faltering"

Although mixed-longitudinal growth curves do not necessarily reflect the growth trajectories of individuals, we can infer that the average child follows an initial growth trajectory that places her at around the 5th percentile of the appropriate reference weights and heights by 2–3 years of age. Rates of growth then appear to be similar to those in the reference population until about 10 years of age. Consequently, most children never overcome the initial deficits acquired in early childhood. Anthropometric deficits are even greater after about 10 years of age (before which most Western populations show a prepubertal velocity slow-down) and greatest after 12–14 years (the median age range for puberty in girls and boys in the reference populations). The increased mean deficits among teens in all measures of body size relative to the international reference coincide with increased variance in stature among teenagers. Such a pattern is typically observed in cross-sectional and mixed-longitudinal data such as those given here and is best interpreted as due to the growth spurt in individuals coming at different ages rather than reflecting increased sampling errors associated with smaller sample sizes.

These observations generate several important questions. First, why do surviving children in this population fail to catch up with reference medians even by the late teens? Second, given that childhood growth

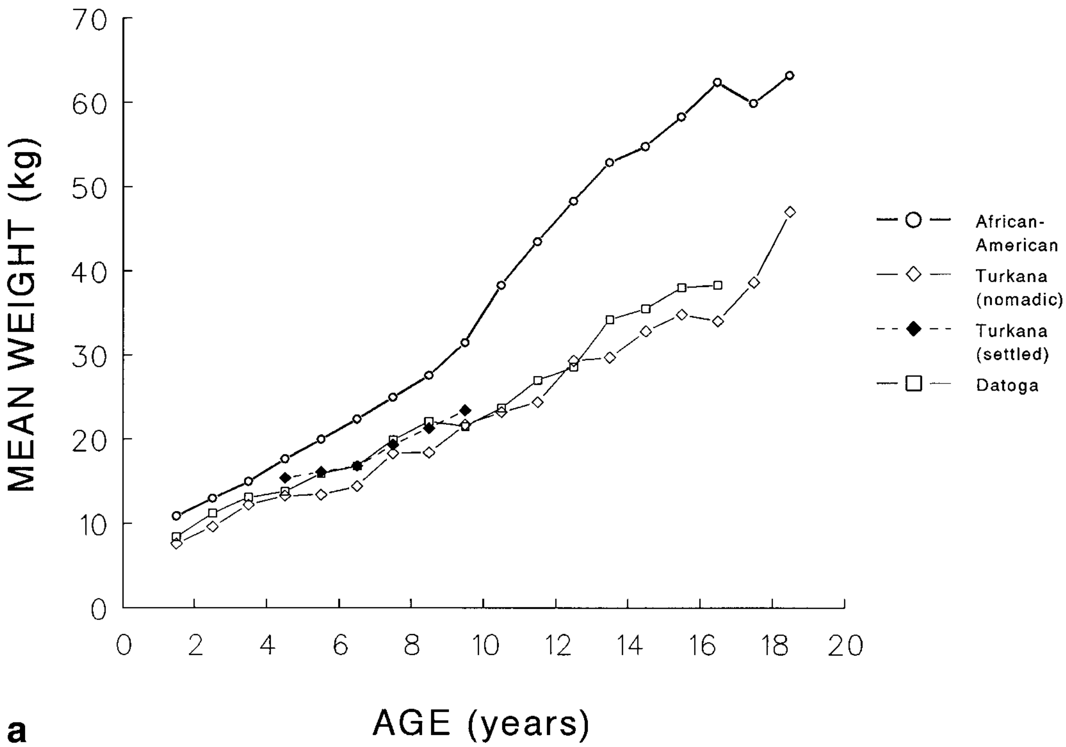


Fig. 6.

retardation has been recorded among several populations of African pastoralists and agropastoralists, how is it that adult stature often falls within the median range of references? Third, are the increased deficits observed among teenagers in all measures of body size relative to the reference population the result of delayed maturation, a cohort effect, or increased environmental insults in this age range? Fourth, how can we account for the observed variation in mixed-longitudinal growth patterns among populations of African pastoralists?

There is debate in the literature as to whether complete catch-up growth (Prader et al., 1963; Eveleth and Tanner, 1990, p. 192) is physiologically possible in children who suffer growth retardation at a young age (Beaton, 1992; Dewey et al., 1996; Golden, 1996). Some observers have concluded that there is little evidence of catch-up growth in later childhood and adolescence (Martorell et al., 1979, 1994; Karlberg et al., 1988; Pelletier et al., 1991). They point out that growth rates appear fairly uniform during middle childhood and adolescence across a variety of settings, so that an early period of growth faltering is followed by, at best, an otherwise normal growth trajectory, rather than an adaptively accelerated growth trajectory. The implication is that human growth potential is "locked in" at an early age (Martorell et al., 1992; Karlberg et al., 1994). Certainly, the cross-sectional growth trajectories reported here suggest that among the Datoga population as a whole, appreciable catch-up does not occur in middle childhood or in the age range corresponding to adolescence in the reference population.

A number of studies have described apparently spontaneous catch-up without intervention in several populations of stunted children (Alvear et al., 1886; Driezen et al., 1967; Keet et al., 1971; Graham and Adrianzen, 1972; Satyanarayana et al., 1981, 1996; Graham et al., 1982; Kulin et al., 1982; Little et al., 1983). We must infer that the insults suffered by the children in these

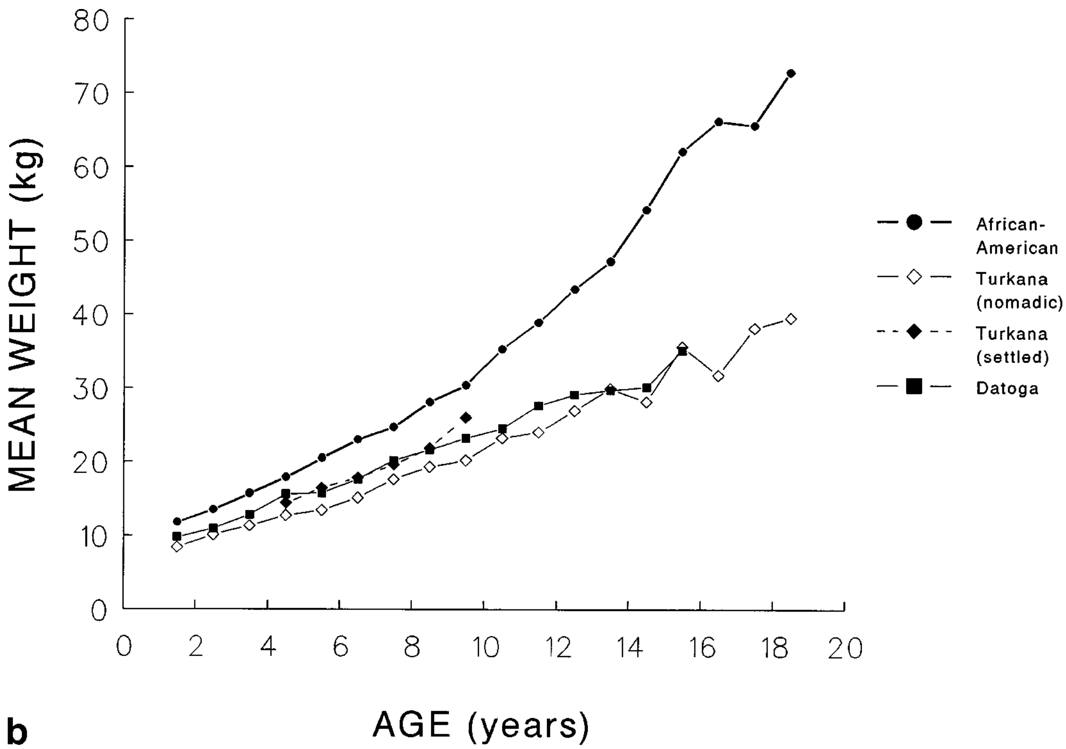
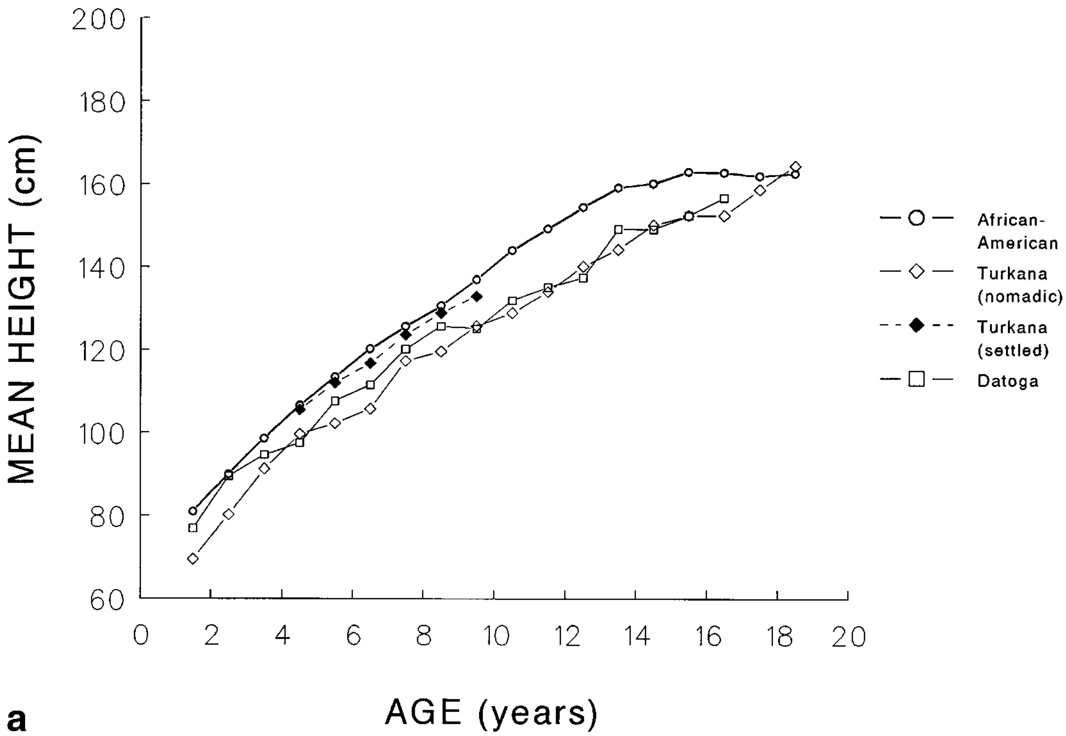


Fig. 6. Comparison of mixed-longitudinal estimates of growth in weight of east African pastoral children. Data on settled Turkana from Little and Gray (1990a), nomadic Turkana from Little et al. (1983), and African Americans from Frisancho (1990). **a:** Girls. **b:** Boys.

studies may have been qualitatively different from those suffered by Datoga children and other stunted populations in which a failure to catch up was reported (Golden, 1996). Other studies have demonstrated catch-up growth among stunted children moved to conditions of better nutrition and lower disease exposure (Graham and Adrianzen, 1971, 1972; Winick et al., 1975; Lien et al., 1977; Goel et al., 1981; King and Taitz, 1985; Mjones, 1987; Schumacher et al., 1987; Steckel, 1987), supplemented with food (Super et al., 1990), or treated for disease (Tanner, 1981). Secular trends of increased height for age and earlier maturation have been reported for populations where improved conditions persist across generations (Eveleth and Tanner, 1990). If environmental change in early childhood can increase growth velocities to allow partial or complete catch-up among those children, then we must infer that the conditions of older Datoga children do not improve sufficiently to allow catch-up. Thus, although Datoga children may experience periods of higher-than-normal growth velocity when recovering from illness or undernutrition, these may not be of sufficient frequency or duration to compensate for the deficits accrued. This hypothesis assumes full catch-up is possible, but is not observed because the environment and diet remain the same throughout the life span (Golden and Golden, 1991). Further research is needed to determine whether the lack of catch-up growth in later childhood is attributable simply to continued inadequacy of food intakes and high infection rates among older children. It is also possible that increased energy demands of herding work and arduous household maintenance tasks such as collecting water and fuel wood act as further stresses on older children and contribute to stunting (Satyanarayana et al., 1986; Spurr, 1987; Sellen, 1998a).



a

Fig. 7.

Despite the apparent lack of catch-up in childhood and the early teen years, data on adult stature among Paranilotic pastoralists suggest that delayed initiation or prolongation of the adolescent growth period can recuperate a proportion of early growth deficits. Apparent evidence of catch-up growth exists for some populations with demonstrably delayed maturation, notably American slaves (Steckel, 1987) and the Turkana pastoralists described by Little et al. (1983). Continued growth beyond 17 years (when reference populations approach an asymptote for stature) has been reported in a number of (mostly rural) populations (Bowie et al., 1980; Kulin et al., 1982; Steckel, 1987). Although the Datoga, Turkana (Galvin et al., 1994), Borana (Galvin et al., 1994), Maasai (McCabe et al., 1989), Bororo (Loutan and Lamotte, 1984), Fulani (Hilderbrand, 1985), Kel Tamaheq (Wagenaar-Brouwer, 1985), Rendille (Nathan et al., 1996), and other populations are stunted during childhood and adolescence, cross-sectional studies indicate that populations move back to the reference median range of stature by adulthood (Little et al., 1983; Sellen, 1996). For example, at 12 years of age, Datoga girls were on average 17.1 cm shorter than African American girls. The observed mean height for Datoga women (158.8 ± 6.2 cm, n = 216) is only 2.7 cm less than that of African American women 18–74.9 years of age (Frisancho, 1990; Sellen, 1995). Similarly, although at 12 years of age Datoga boys are on average 8.7 cm shorter than African American boys, the observed mean height for Datoga men (169.6 ± 6.4 cm, n = 20) is only 4.6 cm less than that of African American men 18–74.9 years of age. Thus, among the Datoga, delayed puberty may facilitate catch-up in stature by extending the time window for skeletal growth. One interpretation of the increased deficits observed among teenagers in all measures of body size relative to the reference population is that they result from delayed maturation.

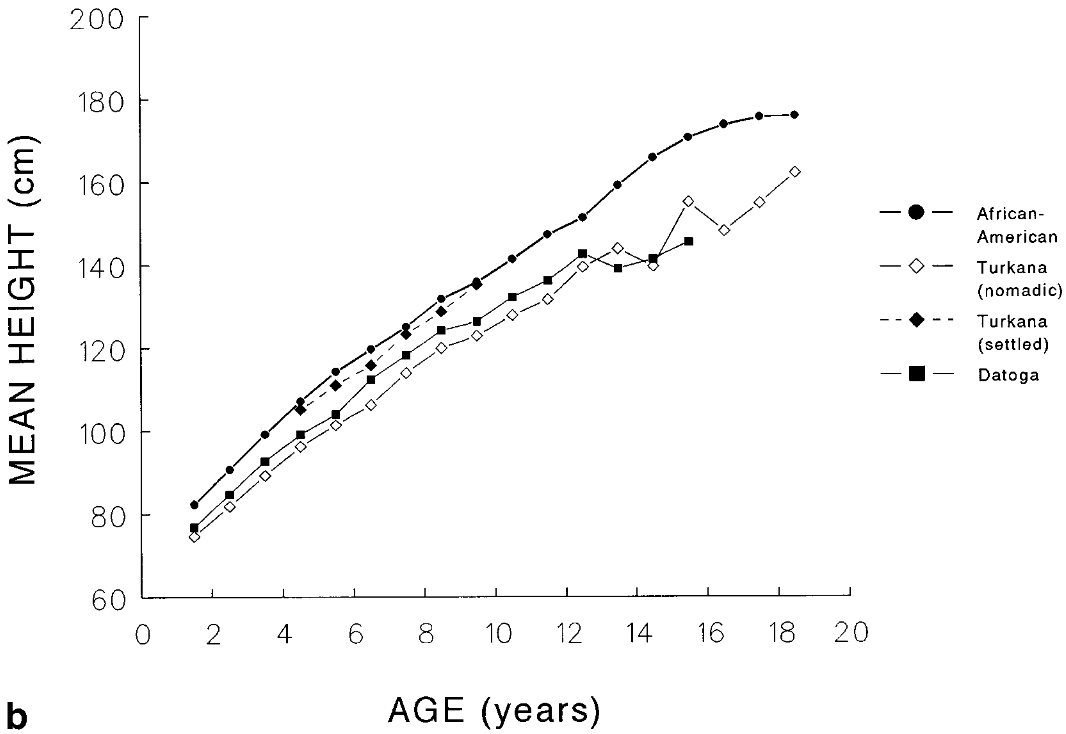


Fig. 7. Comparison of mixed-longitudinal estimates of growth in height of East African pastoral children. Data on settled Turkana from Little and Gray (1990a), nomadic Turkana from Little et al. (1983), and African Americans from Frisancho (1990). **a:** Girls. **b:** Boys.

This interpretation is potentially flawed because it relies on US reference data to make inferences about catch-up growth from cross-sectional data, and takes no account of possible ethnic or genetic differences in key aspects of adolescent growth (Martorell et al., 1994). In order to properly assess the extent to which catch-up is occurring, it is necessary to know whether the "height potential" of these children is similar to that of the reference (Golden, 1994). It has been suggested that Nilotic and Nilo-Hamitic adults may be genetically predisposed to be taller than standards due to differences in rates of growth, length of the growth period, and timing of puberty (Eveleth and Tanner, 1990). The observation that achieved mean heights of adult African pastoralists are rather similar to those in the international standards (Sellen, 1996) does not rule out the possibility that environmental factors constrain expression of a differing genetic potential. However, there is no direct evidence that African populations are genetically predisposed towards delayed maturation relative to other populations. Since the growth patterns of American black and white populations are very similar during adolescence (Frisancho, 1990), it is plausible to interpret the growth patterns of the Datoga as reflecting a failure to catch up on early growth stunting during middle childhood and possibly a delay in adolescent growth spurt.

It is unfortunate that reliable maturity measures could not be collected during the surveys yielding this sample, so that we can only speculate on the timing of puberty. Since current consensus is that skeletal maturation is usually not delayed to anywhere near the extent of linear growth, so that the actual period of growth is not sufficiently extended to allow compensation for growth deficits (Proos et al., 1991; Proos, 1992; Martorell et al., 1994), this aspect of Datoga growth warrants further investiga-

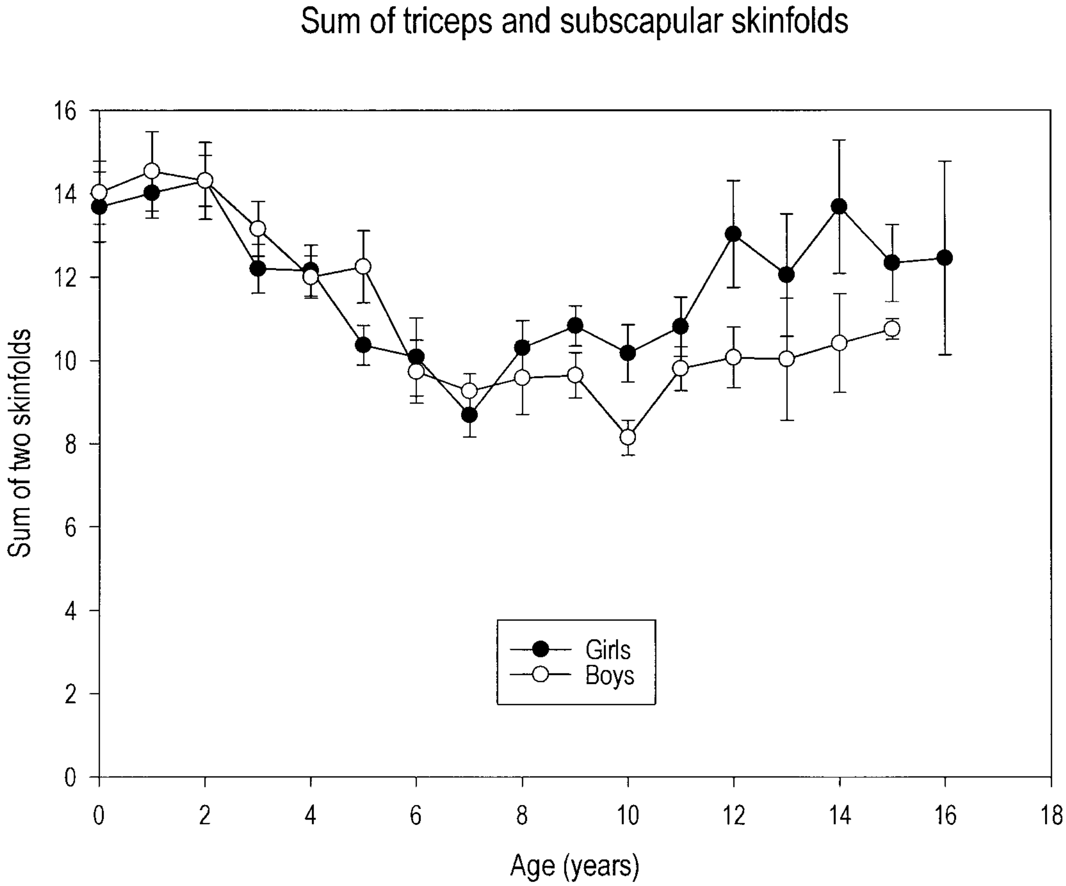


Fig. 8. Age distribution of adiposity in Datoga children.

tion. The present data suggest that much greater delays and adolescent deficits may occur among boys. The increases in upper arm fat observed after 8 years in girls and 11 years in boys may correspond to the preadolescent or adolescent increase in adiposity observed in Western populations (Fig. 9). For girls, the increase in mean height and its variance at 13 years may result from a growth spurt in height at 12–13 years, but sample sizes are small. The mean height for adult women in this population (158 cm) appeared to be achieved by about 18 years of age (Table 2), the same age as in the multiethnic US reference. Among boys there is little indication of an increase in height velocity between 13–16 years. Indeed, the very low mean height at 16 years, which falls at only the 1st percentile (80% of standard median), may result from a significantly delayed growth spurt. For boys to reach adult heights, growth must continue far beyond 18 years. The exceptionally low mean weights among teenagers are also consistent with the hypothesis that growth is further compromised during early adolescent years, adding to the weight deficits already established in early childhood.

It is possible that both a cohort effect and undersampling of larger older children confounded the mixed-longitudinal presentation of the data. A cohort effect might account for the greater growth deficits among children born before 1976, and particularly among boys born in the late 1970s. Ethnographic research failed to reveal any significant events that could be inferred to have improved the relative growth status of chil-

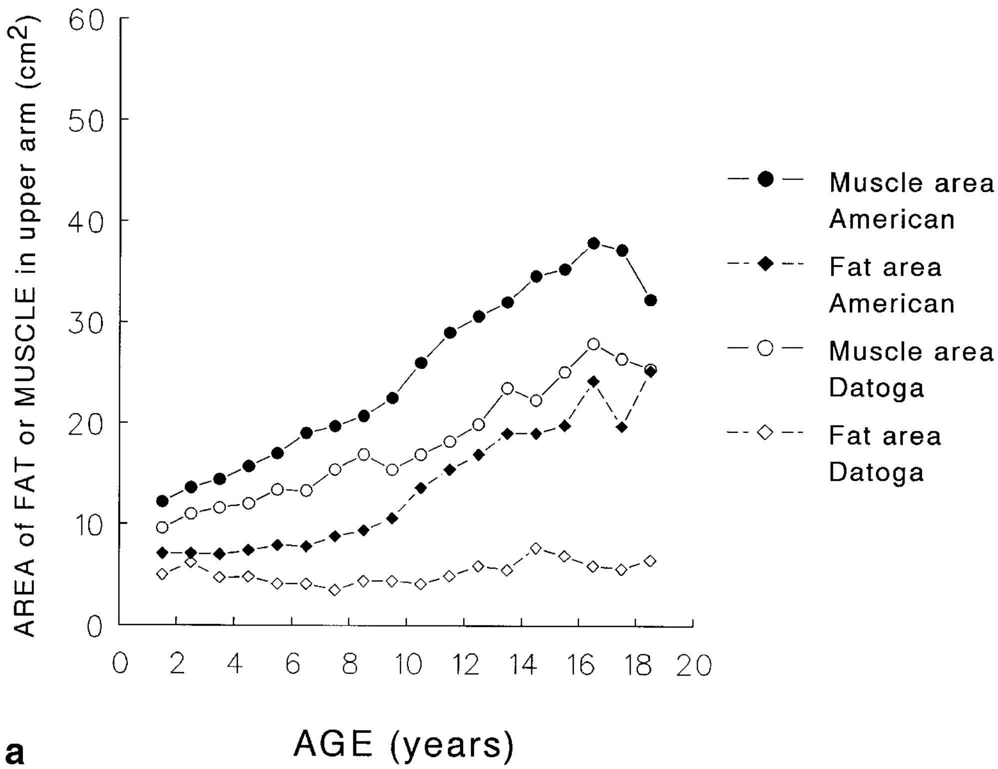


Fig. 9. (See legend page 206.)

TABLE 3. Estimated point prevalence of illness among children age 0–3 years

Primary symptom cluster (based on pooled monthly caregiver assessments for the previous 24 hr)	Illness prevalence (% of days sampled, n = 186)
Fever/malaria	14.5
Respiratory (±fever)	11.3
Other	15.3
Diarrhea without other symptoms	1.0
Total illness prevalence	42.1
Total nondiarrheal illness prevalence	41.1
Combined diarrhea with other symptoms	29.6

dren born after that date and surviving to measurement, such as reduction in the frequency or severity of droughts or livestock losses due to raiding or epidemics. The patterns might also be attributable to biased sampling of more poorly growing children in the community, perhaps because they were more likely to be found in the vicinity of the homestead rather than to be out working when the researchers visited. This is unlikely because, based on census data collected for all households included in the surveys, anthropometric coverage of older children was almost complete.

In many regards, the Eyasi Datoga may be a good model for many other African pastoral populations, and inferences drawn from results of this study may be valid in a wider context. However, children in the Eyasi Datoga population appear to fall towards the lower end of the observed range of variation in anthropometric status among African pastoral populations (Galvin et al., 1994; Sellen, 1996). It is most parsimonious to interpret variation in pastoral growth patterns as the result of underlying physiological responses of individuals to poor nutrition and/or disease stress rather than genetic factors. It is not clear why the Datoga, despite being taller and heavier for age as children, become shorter than the Maasai, Turkana, Tutsi, and other nomadic pastoral as adults. It is likely that a deficiency

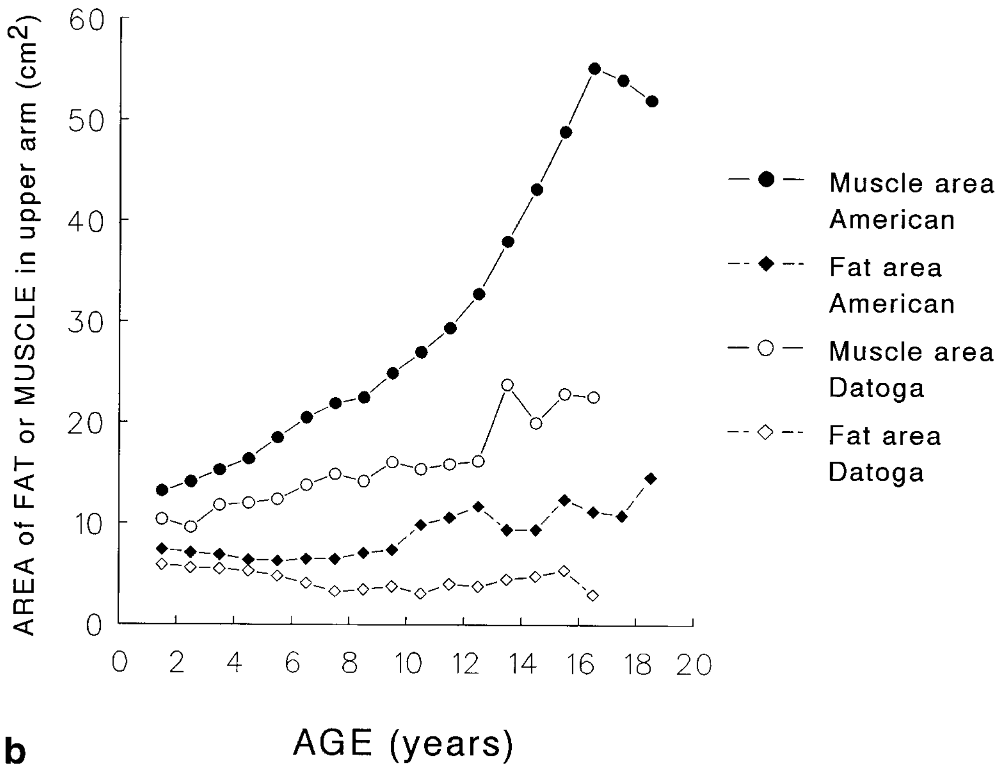


Fig. 9. Upper arm composition of American and Datoga children. **a:** Girls. **b:** Boys.

of type II micronutrients (Golden, 1988, 1997; Brown, 1991; Hambidge, 1992) is limiting growth to a greater extent among the Datoga, who have a remarkably monotonous diet based on maize with only infrequent consumption of meat, vegetables, and relatively lower intakes of milk products. The sex difference may indicate that zinc in particular, available mainly from meat, limits growth, because the effects are always greater on males (Walravens et al., 1989).

CONCLUSIONS

Cross-sectional anthropometric observations show that the growth status of Datoga children is generally very poor relative to Western reference data, but may be typical of African pastoralists. Most of the growth deficits are established in the first 2–3 years of life. This may be a critical period in which the behaviors of Datoga parents might most strongly influence the survival of their offspring. Catch-up growth during later childhood, if it occurs at all, is not sufficient to overcome the growth deficits established in the early years, and there is a strong pattern of increasing deficits with age relative to reference populations. Some unusual patterns of teenage growth may indicate maturational delays and an extended skeletal growth period. Alternatively, although we do not yet have data to assess the relative importance of energy balance, micronutrient supply, and disease factors in the etiology of growth retardation, increased stunting among teenagers, particularly boys, may be a specific result of the type of labor demands placed on them. Further work is need to test the hypothesis that puberty is delayed among the Datoga and to investigate the interactions of genetic and environmental factors. These observations have implications both for understanding the biology of the pastoral adaptation in human evolution and for nutrition and development policy. We predict stronger selection for pa-

rental investment in younger offspring in societies following an arid pastoral subsistence strategy. We also predict that interventions to improve growth performance and nutritional status of children in pastoral populations would be most effective if targeted at the very young.

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